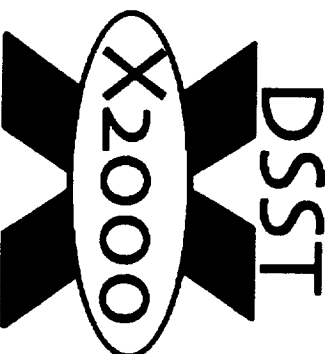


The X2000 Program – an Institutional Approach to Enabling Smaller Spacecraft



Les Deutsch, Chris Salvo

Deep Space Systems Technology (DSST) Program

Dave Woerner

X2000 First Delivery Project

Visit the DSST web site at <http://www.dsst.jpl.nasa.gov>

April 14, 1999



The X2000 Program Introduction to X2000 The Old Days



- Missions were large and expensive
- A new deep space mission "start" occurred only every few years
- Mission budgets were large enough to do substantial technology development
- Technology used on one mission would be obsolete by the next mission





JPL

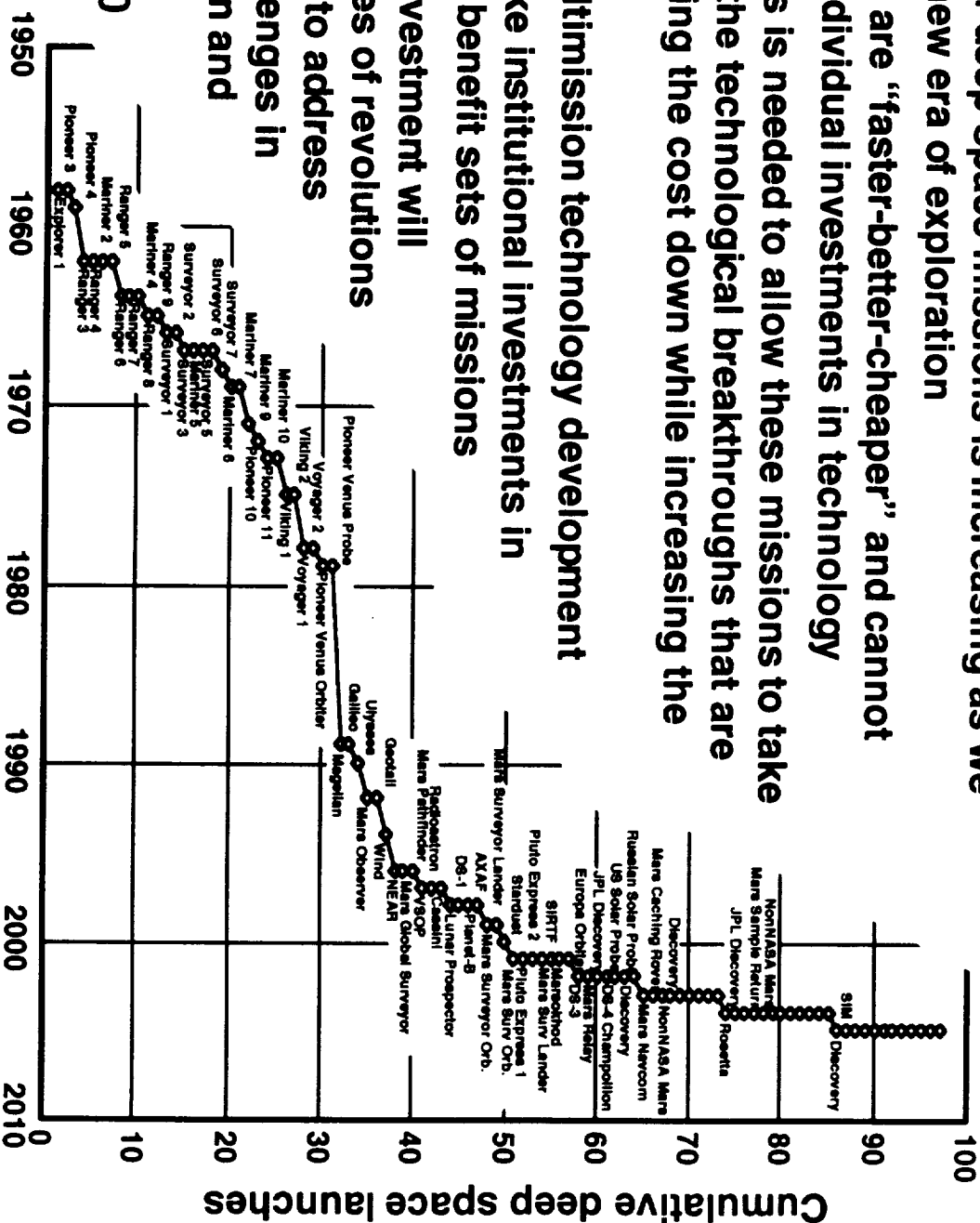
The X2000 Program

Introduction to X2000

The Future

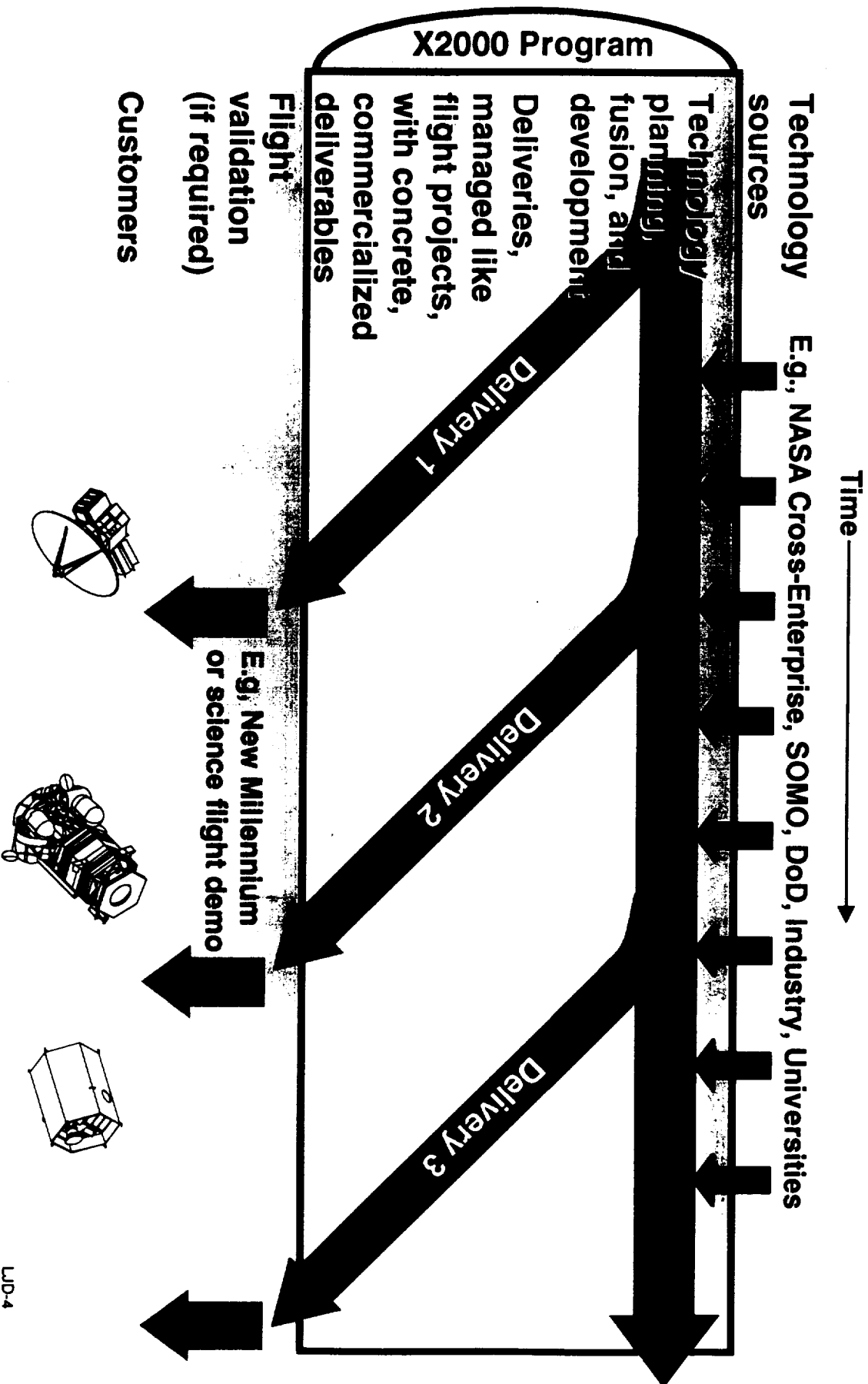


- The number of deep space missions is increasing as we embark on a new era of exploration
- New missions are "faster-better-cheaper" and cannot afford large individual investments in technology
- A new process is needed to allow these missions to take advantage of the technological breakthroughs that are critical to getting the cost down while increasing the science
- The key is multimission technology development
- NASA will make institutional investments in technology to benefit sets of missions
- Continuous investment will provide a series of revolutions in technology to address common challenges in mission design and execution
- This is X2000





The X2000 Program Introduction to X2000 X2000 Concept

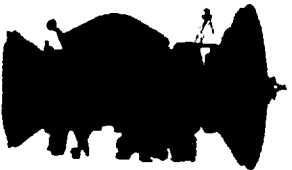




The X2000 Program

Introduction to X2000

The Trend Toward Smaller Spacecraft



Cassini



Mars
Pathfinder



Lewis



Mars 98 Lander/Orbiter



Stardust



Solar Probe



Pluto/Kuiper
Express



Europa
Orbiter



"Microspacecraft"

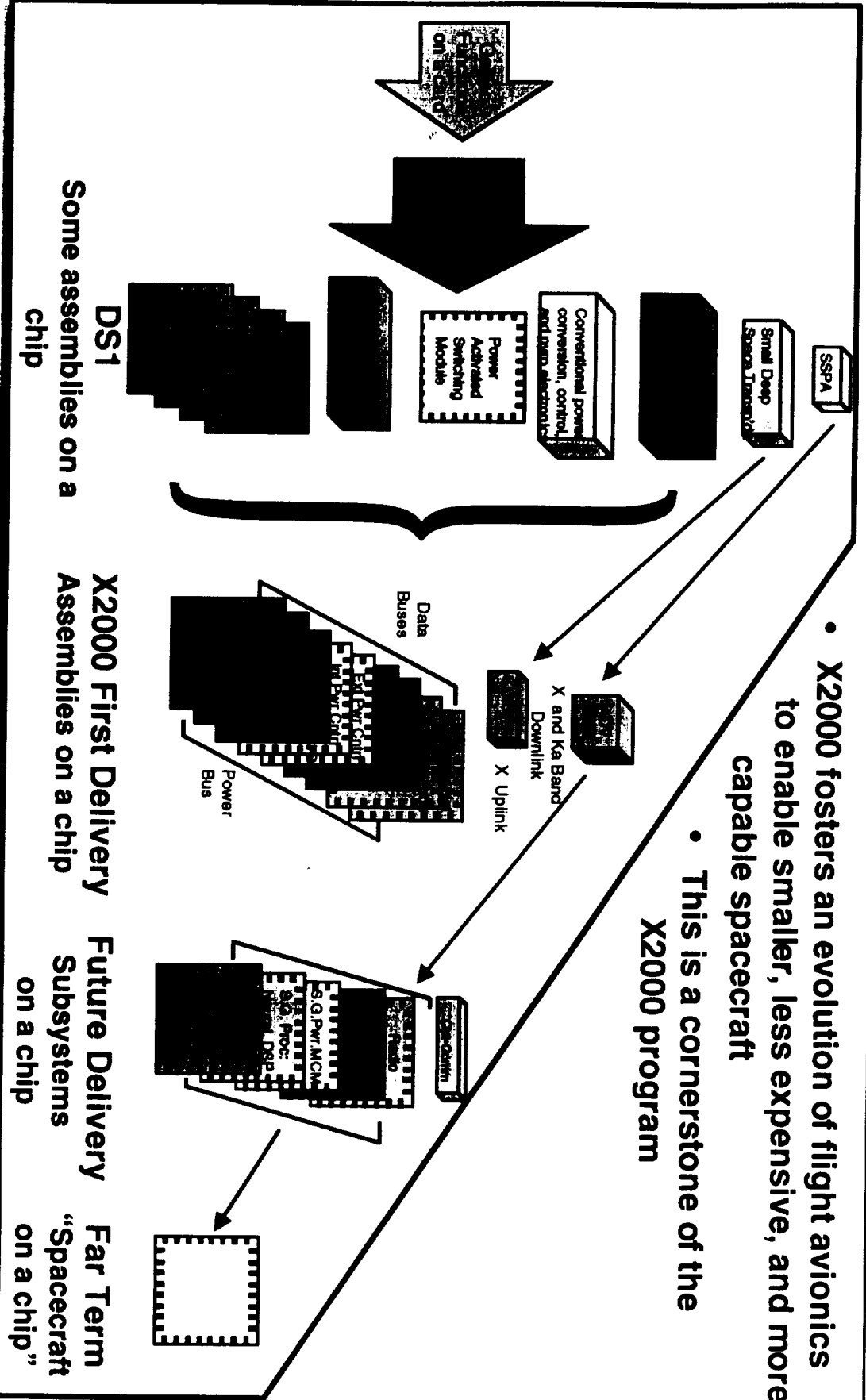


The X2000 Program Introduction to X2000 Avionics Miniaturization



• X2000 fosters an evolution of flight avionics to enable smaller, less expensive, and more capable spacecraft

• This is a cornerstone of the X2000 program





The X2000 Program

Introduction to X2000

Program Top-Level Organization



- **Deep Space Systems Program**
 - **X2000 First Delivery**
 - **X2000 Future Deliveries**
 - **Mission Data System**
 - **Advanced Radioisotope Power Source (ARPS)**
 - **Center for Integrated Space Microsystems (CISM)**

Introduction to X2000

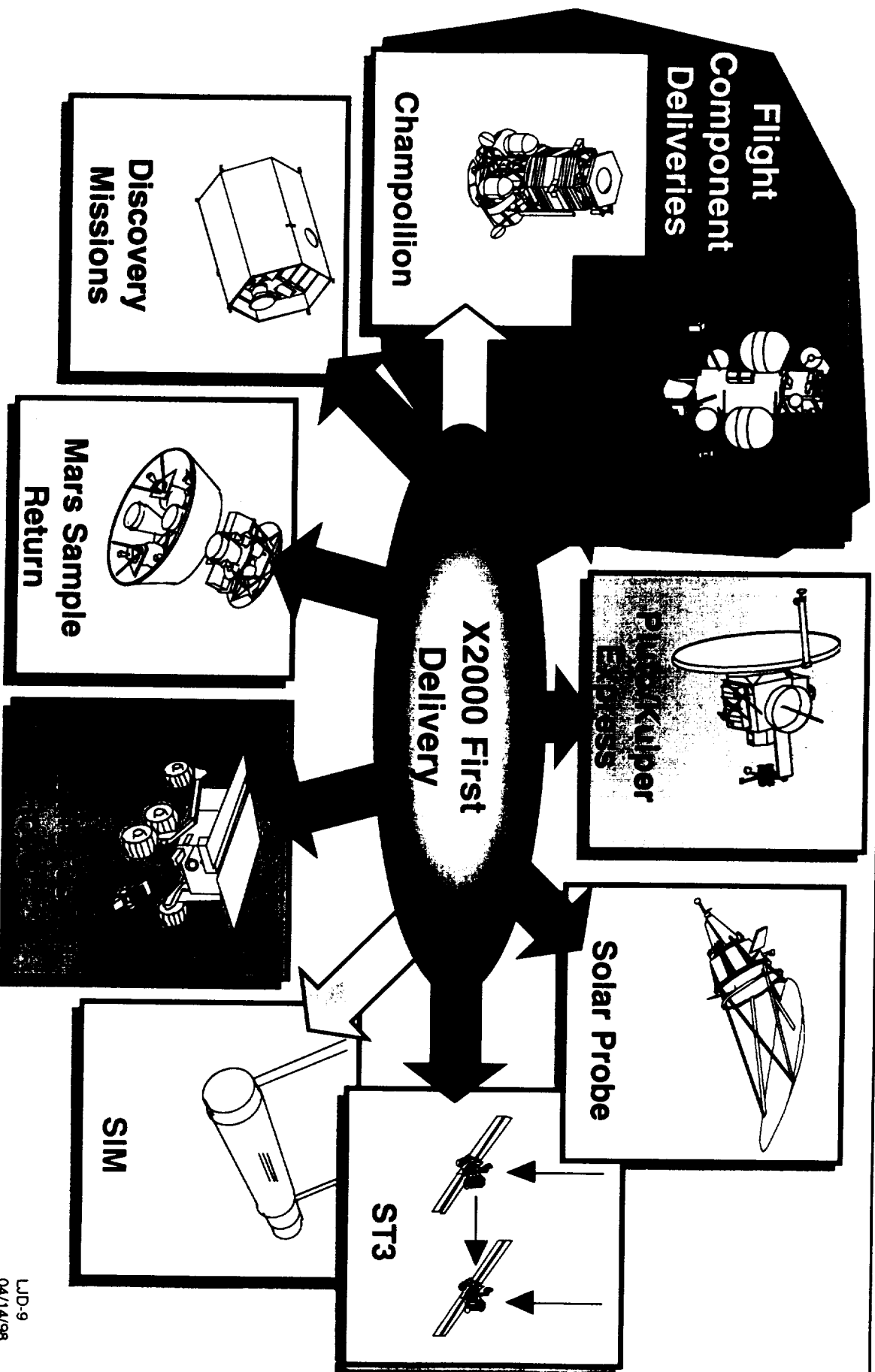
X2000 First Delivery



- **General**
 - Scalable, modular, long life
 - Radiation hardened designs, parts, & materials
 - Sensor/instrument input and output
- **Avionics**
 - Computer, local memory, mass memory
 - Power & pyro switching
 - Power system control
- **Communications**
 - Spacecraft transponding modem (STM) with X and Ka-band capabilities
- **Flight and Ground software (MDS)**
 - Operating systems
 - Generic auto-nav, 3-axis attitude control
 - Generic flight/ground autonomy
 - Generic flight/ground science data processing
 - Generic ground command/telemetry processing & display
- **Advanced Radioisotope Power System (ARPS)**
- **High efficiency 0.9N thruster**



The X2000 Program
Introduction to X2000
Customers for X2000 First Delivery

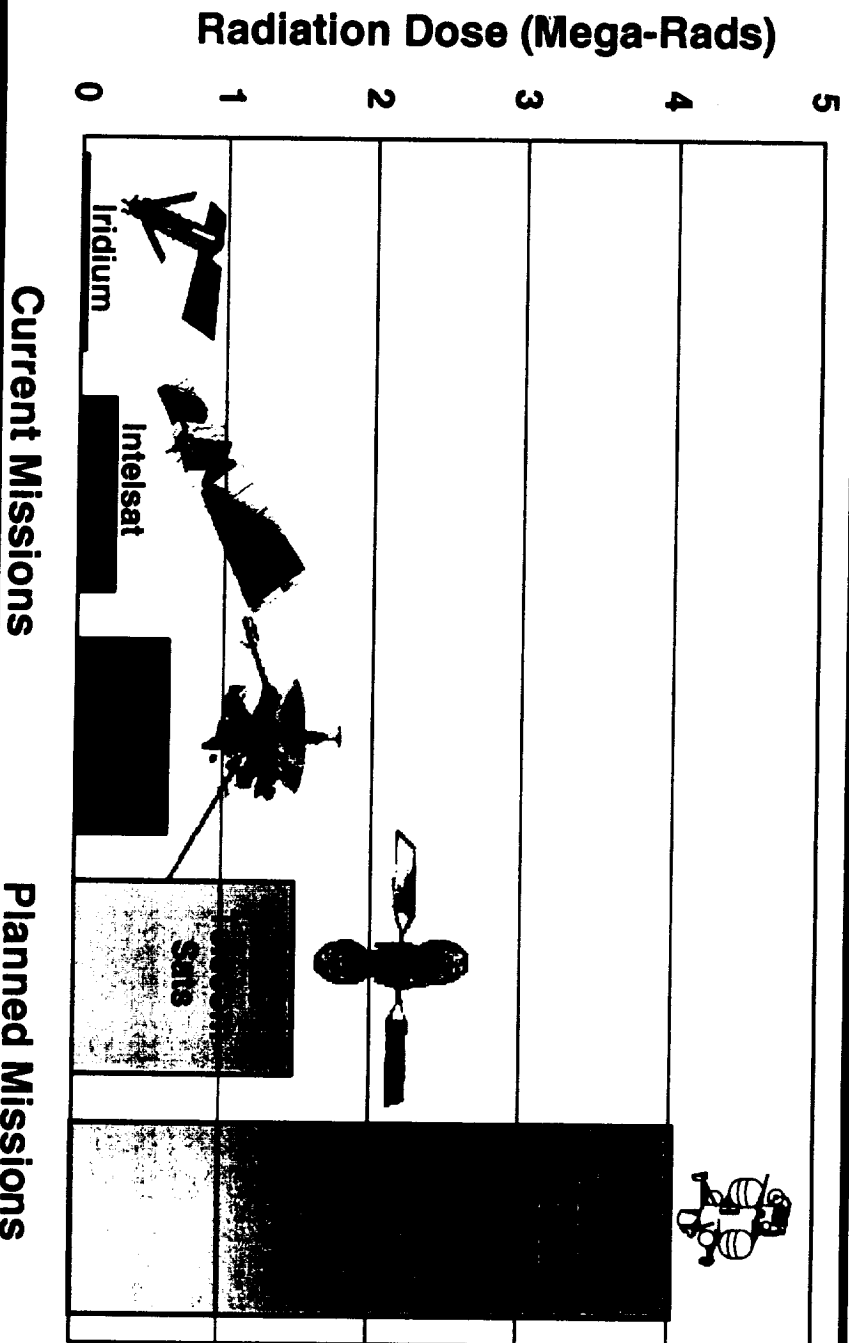




The X2000 Program Introduction to X2000 Radiation-hard Delivery



- X2000 First Delivery will deliver radiation-hard capabilities
- Designs and components will also be useful for commercial endeavors
- Design will survive in LEO, GEO, and deep space, and enables MEO missions
- Design will also handle SEUs and will be immune to particle-induced latch-up

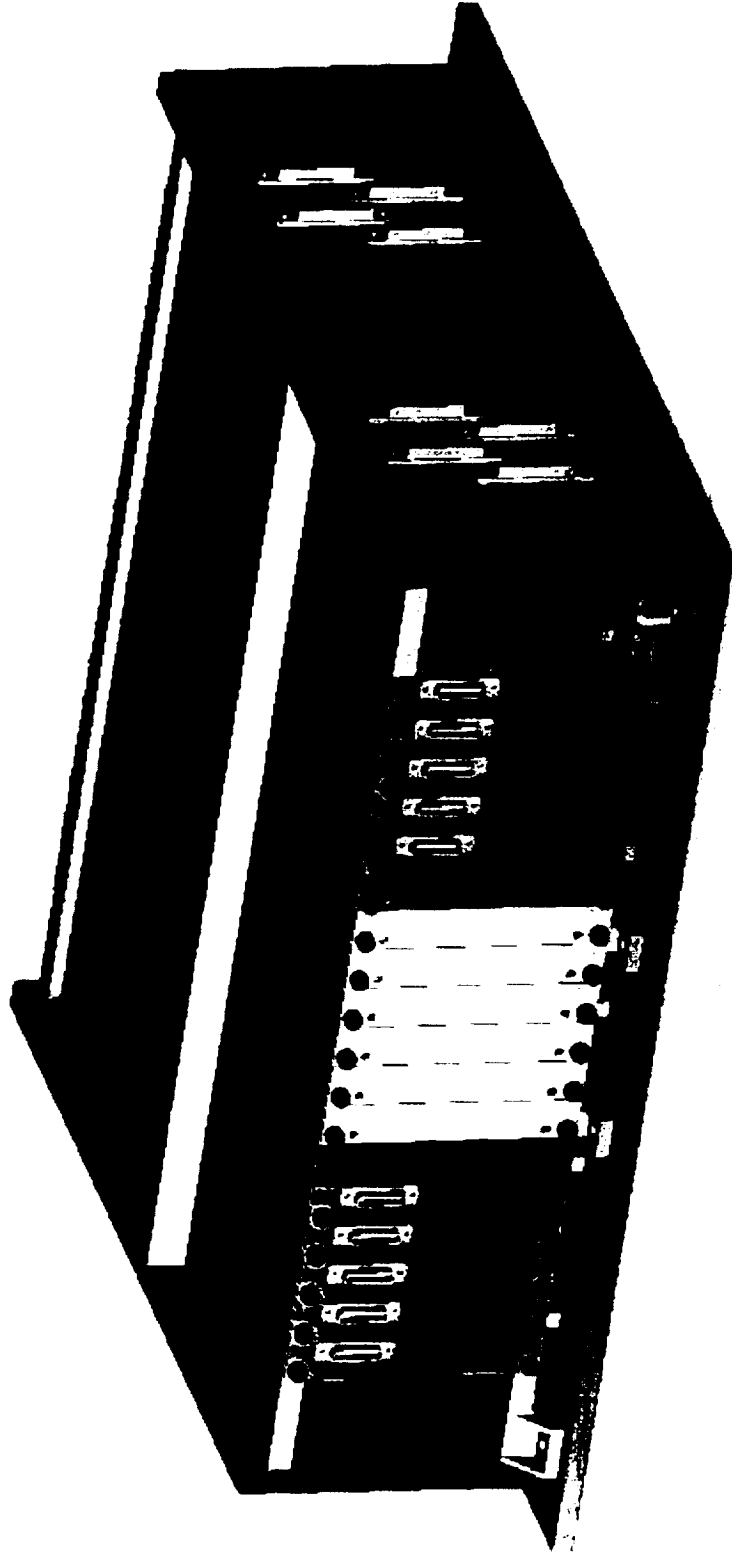




The X2000 Program Introduction to X2000 X2000 System Construction



- The 9 slices are inserted into customized CPCI card cages
- Additional cards can be added by individual spacecraft to add functionality beyond the X2000 core





The X2000 Program

Introduction to X2000

Advanced Radioisotope Power System (ARPS)

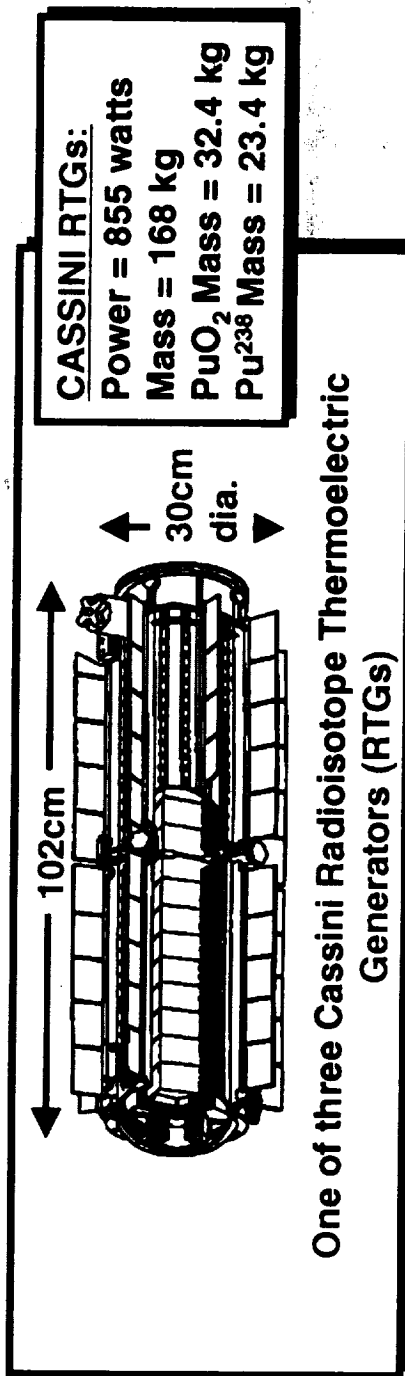
DSST
X2000

- X2000 is developing, in partnership with DoE, an advanced, highly efficient radioisotope power system that dramatically reduces the use of radioactive material for U.S. space missions – will be part of X2000 First Delivery

Today:

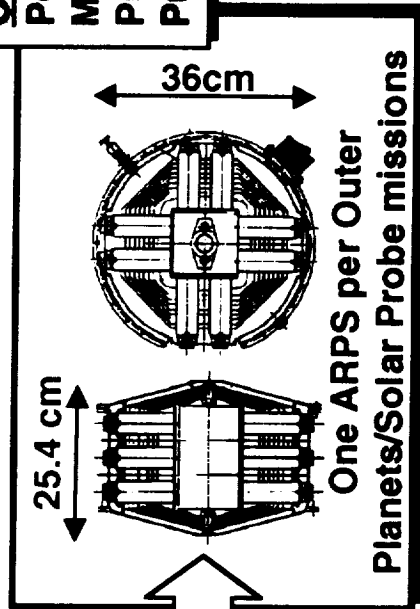
X2000/ARPS

Future:



QP/SP ARPS:

Power = 150 watts
Mass = 16 kg
PuO₂ Mass = 3.0 kg
Pu²³⁸ Mass = 2.2 kg



AMPS

LOCKHEED MARTIN

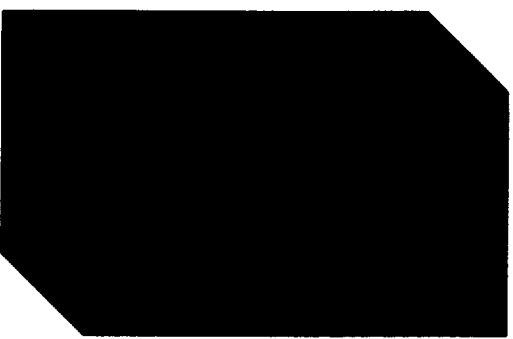
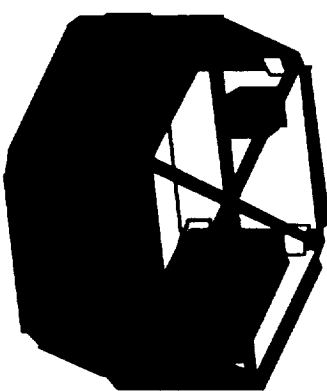
LJD-13
04/14/98



The X-2000 Program

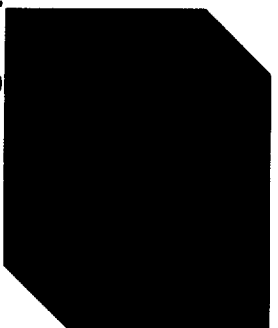
Introduction to X2000

Center for Integrated Space Microsystems (CISM)



1st Delivery Electronics

- Power electronics
- Telecom processing
- 3D multichip module standard
- Integrated architecture



Avionics System-on-a-Chip

- Begin design and fabrication of minimum avionics system-on-a-chip.
- Telecom, power management, CPU, memory, and sensors.

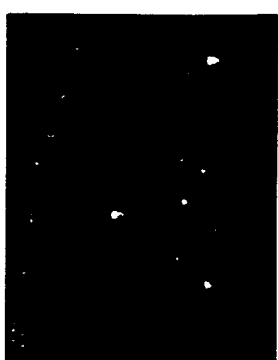


Revolutionary Computing

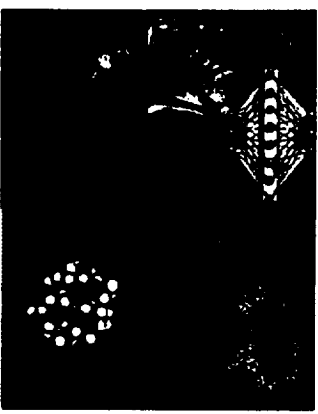
- Reconfigurable computing
- Ultra-low-power electronics
- Quantum computing
- MEMS-Optics, etc.



The X2000 Program
Introduction to X2000
CISM: Revolutionary Computing Technologies



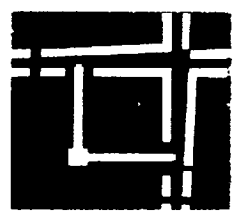
Quantum Dots



Biological Computing



Quantum Computing

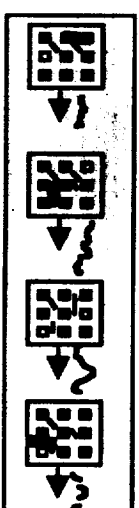


Optical Computing

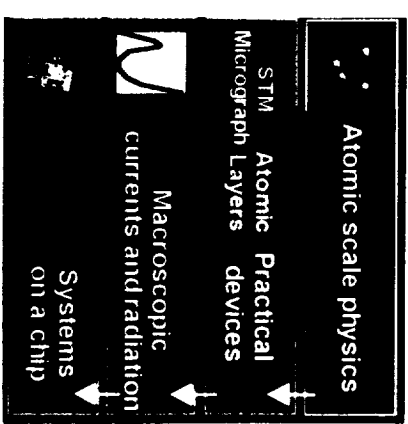
"Mission - inspiring"
Breakthrough
Revolutionary Computing
Technologies &
Architectures



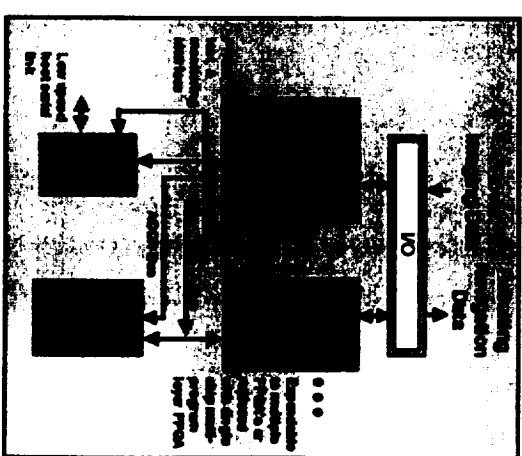
DNA Computing



Evolvable Hardware



Nano-technology Modeling



Reconfigurable Computing

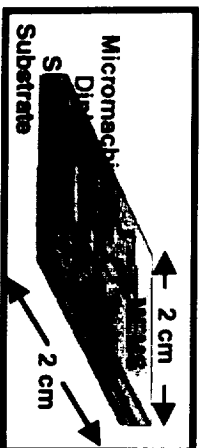


JPL

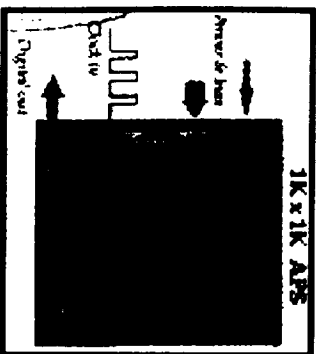
The X2000 Program

Introduction to X2000

CISM: System on a Chip (SOAC)



Micromachined front end for miniaturized RF comm system



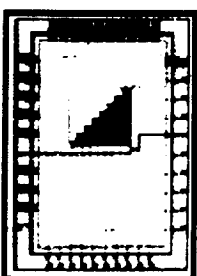
Active Pixel Sensors for low-power optical comm. & advanced star



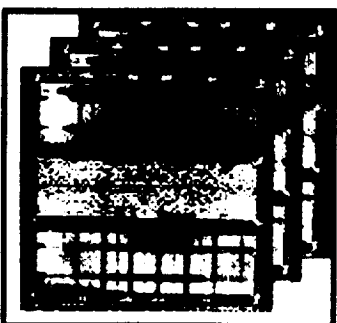
Thin film microtransformers & passive components for miniaturized power management and distribution



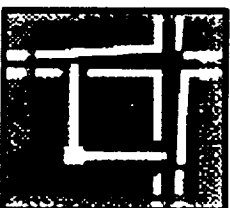
X2000 First Delivery:
~10,000cc, ~60 kg, ~150W



Ultra-low-power architecture & devices



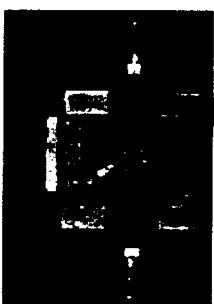
Processor in memory:
Multiple CPU/chip with DRAM, SRAM, NVDRAM, BIST, fault



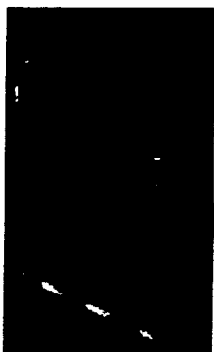
High bandwidth, low power, optoelectronic switch for high speed optical bus



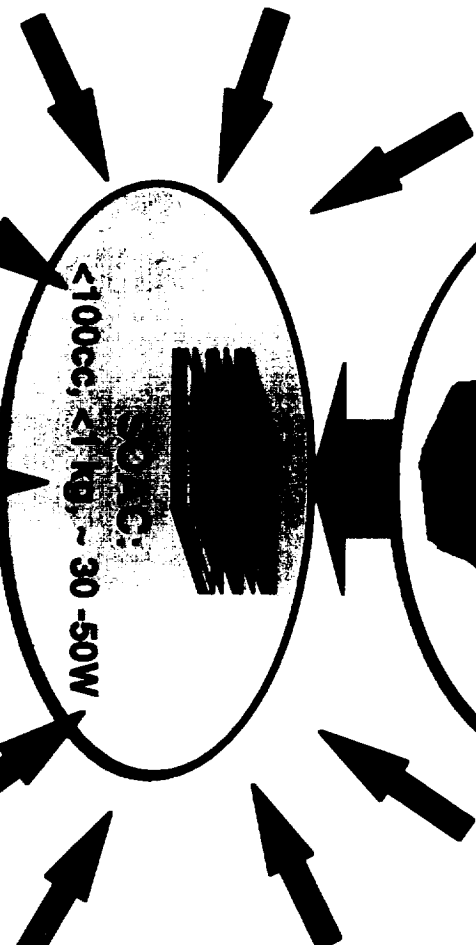
Thin film batteries for on-chip power storage



Thermoelectric thin film coolers for advanced thermal control



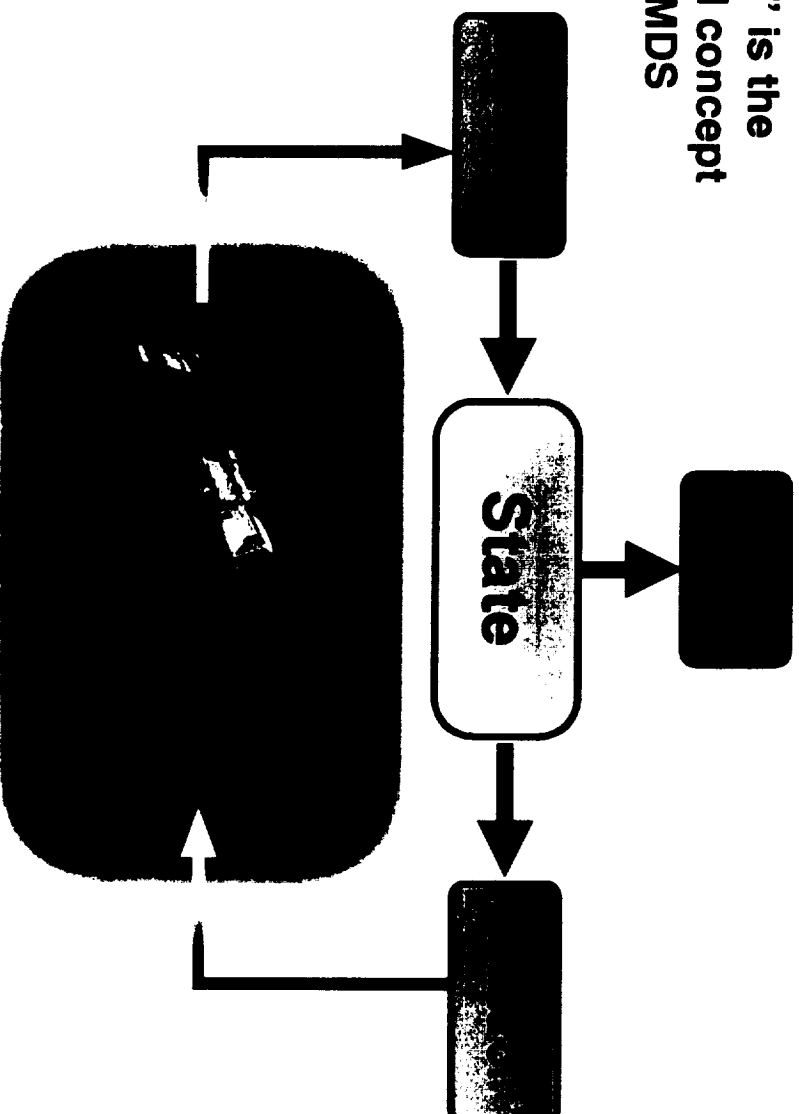
Micromechanical inertial reference system for mini guidance & nav



SOAC:
<100cc, <1 kg, ~ 30-50W

The X2000 Program
Introduction to X2000
The Mission Data System (MDS)

- The MDS is the glue that holds X2000 together
 - Includes all flight and ground software required to provide delivered functionality
 - Embodies the end-to-end system architecture
- “State” is the central concept of the MDS





The X2000 Program

Introduction to X2000

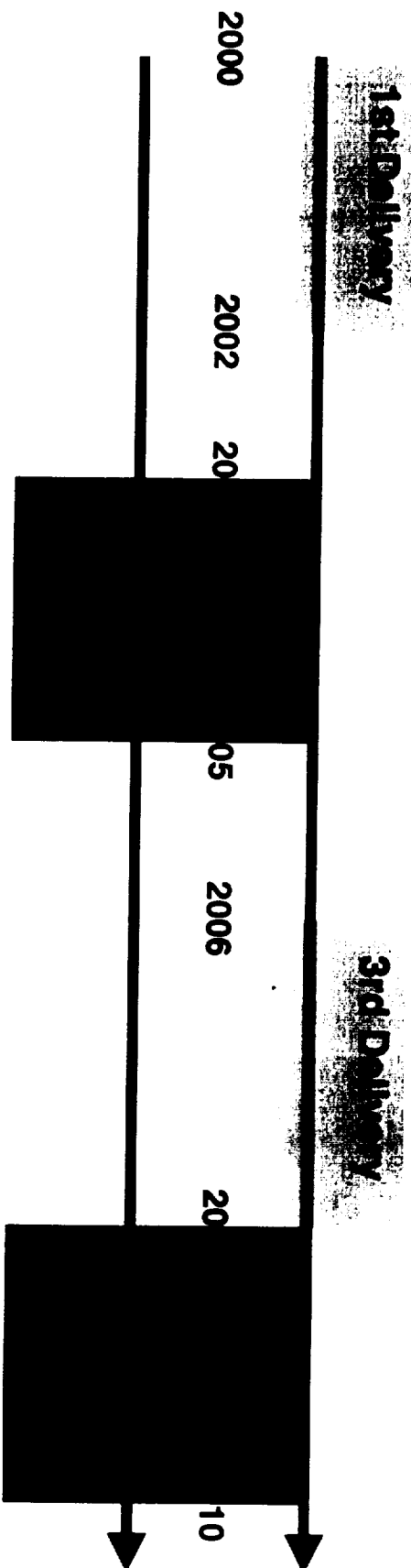
X2000 Future Deliveries Vision



- On 4-6 year centers, revolutionize the *remote sensing, full spacecraft* capability.
- In between these deliveries, enable *new systems* for new exploration approaches and provide a path for progress towards the next revolution.

Sharpening capabilities (orbiters, flybys, probe carriers, landers, ...),

broadening the exploration toolset (penetrators, aerobots, subsurface systems, ...)



NASA

JPL

The X2000 Program

Introduction to X2000

Future Deliveries: Develop Technology for Strategic NASA Missions



Need advanced

capabilities in many

diverse systems:

Orbiters, landers, probes,
rovers, penetrators,
aerobots, aircraft, sub-
surface, submarine, ...?

Mars/Venus Aerobot

Saturn Ring Observer

IVO
Io Volcanic Observer

Small Body In-Situ

Exploration

and Sample Return

NO/TE

Neptune Orbiter/
Triton Exploration

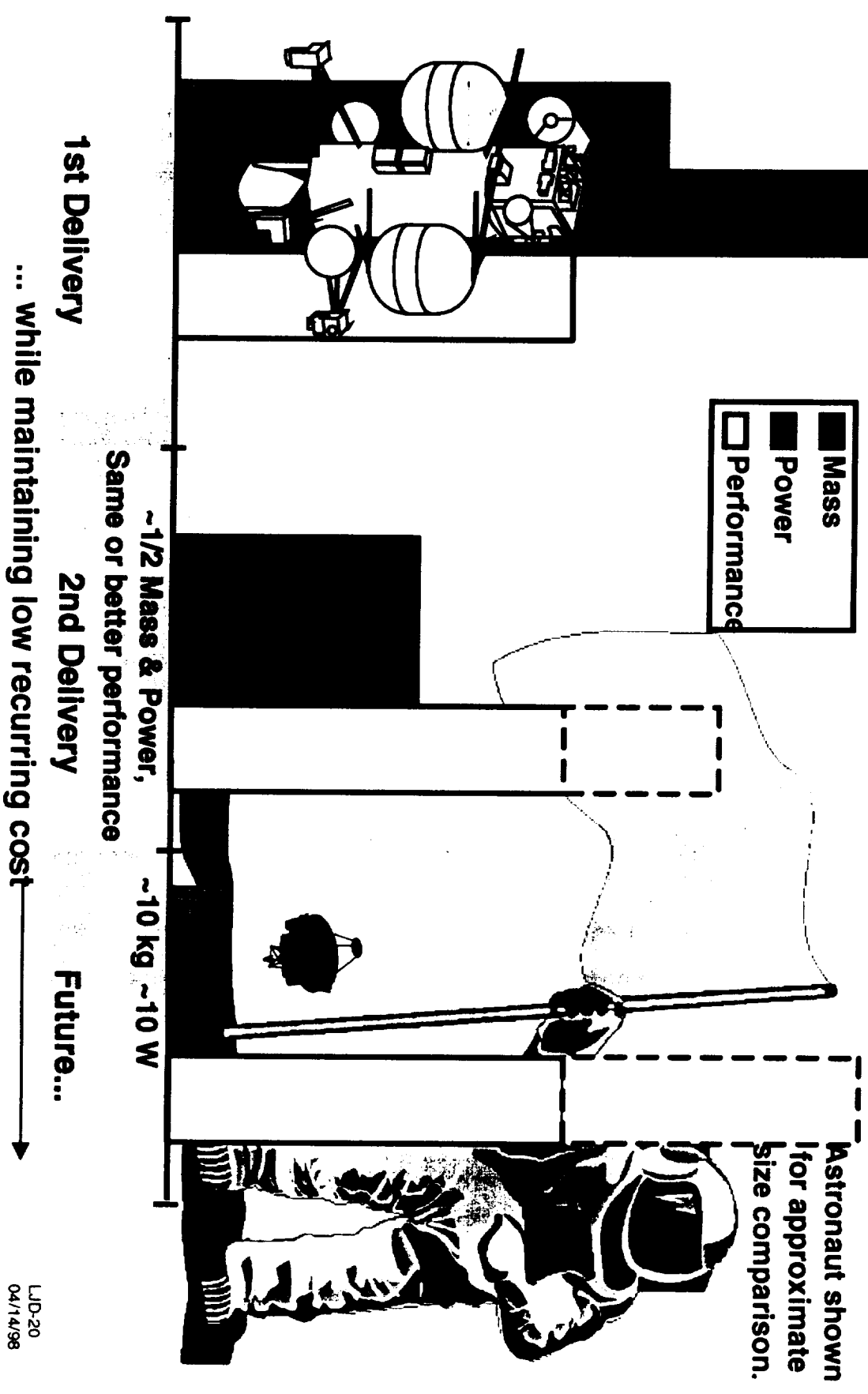
Titan Organic Explorer

Europa Lander

Outer Planet Deep
Multi-Probes

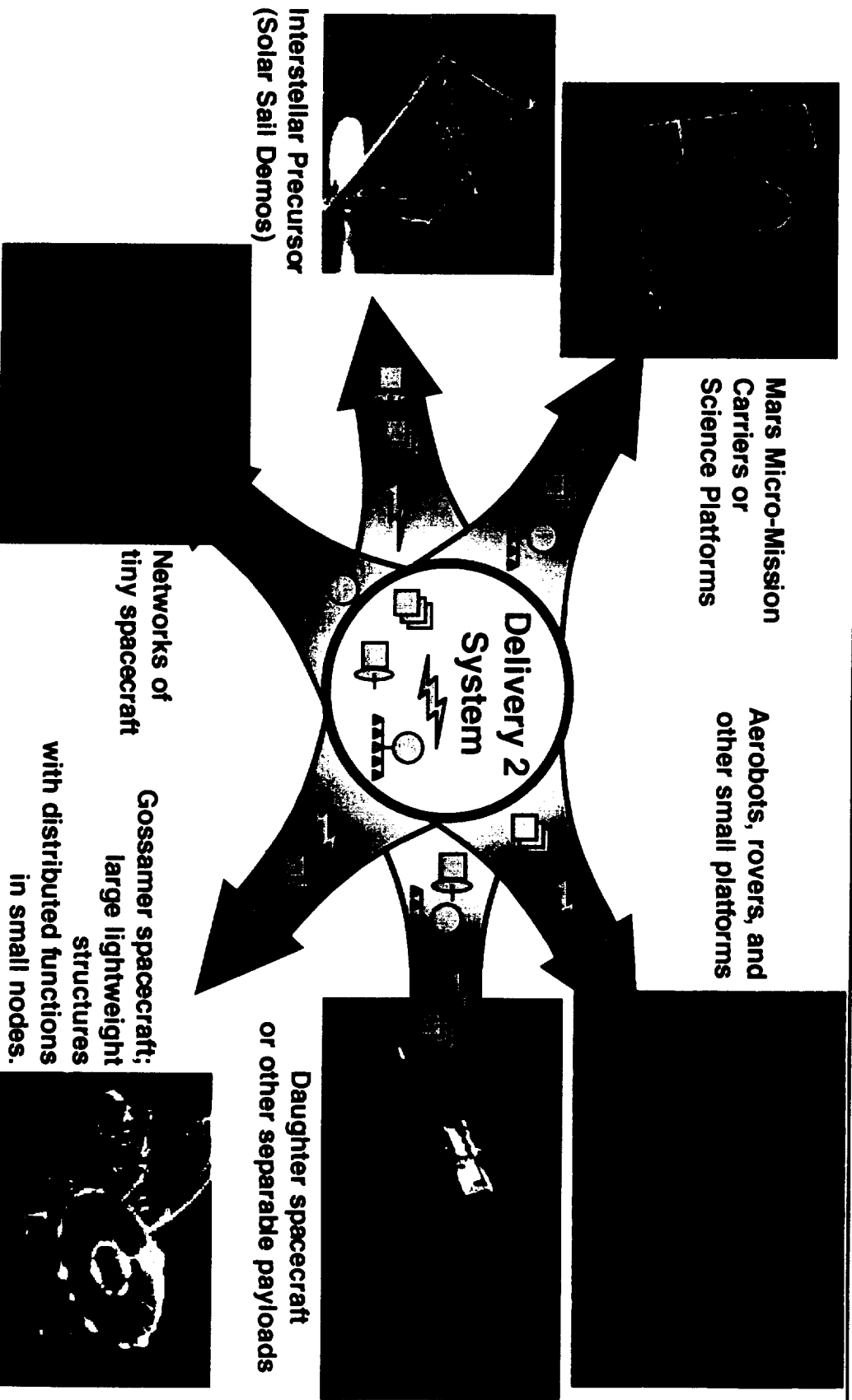


The X2000 Program
Introduction to X2000
X2000 – Trend in Future Delivery Metrics





The X2000 Program
Introduction to X2000
Some Possible Second Delivery Beneficiaries



 Integrated Avionics

 /  = Deep Space/Relay Communications

 = Mini Propulsion



The X2000 Program

Introduction to X2000

Conclusion



- **NASA's X2000 Program is important for two reasons**
 - **It develops the technology that will enable new types of deep space exploration**
 - **It is a new, faster and cheaper process for technology infusion into NASA missions**
 - **It transfers these capabilities to US industry so they are available for future spacecraft**
- **Many of these new capabilities are relevant to Earth missions as well**
- **X2000 will work with the NASA Goddard Space Flight Center (and others) to help make these capabilities available to a larger community**